nificant role to play. Look at it from the other direction. If biological speciation were really analogous in crucial respects to software improvement, it would come about in part because of the mutually interacting rational activities of numerous demigods rather than via natural selection.

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DO CONJUNCTIVE FORKS ALWAYS POINT TO A COMMON CAUSE?

Reichenbach ([1956], p. 159) defines a *conjunctive fork* as an ordered triple of events $\langle A,B,C\rangle$ satisfying the following statistical relations:

$$\begin{aligned} P(A/C) &> P(A/-C) \\ P(B/C) &> P(B/-C) \qquad (1) \\ P(A\&B/C) &= P(A/C)P(B/C) \\ P(A\&B/-C) &= P(A/-C)P(B/-C) \end{aligned}$$

(where $P(X/Y)$ denotes the conditional probability of X given Y, and $-Z$ stands for the non-occurrence of Z). By a short calculation, based on the

fact that $P(X) = P(X/Y)P(Y)+P(X/-Y)P(-Y)$, Reichenbach ([1956], p. 160; *cf.* Salmon [1984], p. 160 n. 2) shows that (1) entails that

$$P(A\&B) > P(A)P(B) \tag{2}$$

i.e., that A and B are not statistically independent. It can be readily seen that relations (1) remain invariant under the mutual exchange of A and B. Conjunctive forks are thus symmetric in their first two terms. On the other hand, relations (1) are not symmetric in A and C, nor in B and C. Reichenbach believed that this asymmetry of conjunctive forks has a causal significance. Three events, A, B and C will constitute a conjunctive fork as above if C is a common cause of A and B. It may indeed occur that a triple $\langle A,B,E\rangle$ is a conjunctive fork, where E is a common effect of A and B. But such can be the case 'only on the condition that there also exists a common cause C satisfying the same relations (1) with A and B' (Reichenbach [1956], p. 162).

Thus Reichenbach claims that the symmetric terms of a conjunctive fork must *always* have a common cause, which may or may not be the third term of the fork. An interest in this claim has been rekindled by Wesley Salmon, in whose book, *Scientific Explanation and the Causal Structure of the World* [1984] , the purported causal significance of conjunctive forks lends some support to the broader claim that statistical relations can provide, if not an *analysis* of causal connections, at any rate sufficient *evidence* of their existence. According to Salmon ([1984], p. 262), 'we have strong reason to believe that conjunctive forks have considerable explanatory force with respect to the order that exists in the universe'.[1]

Salmon ([1984], p. 168) quotes an example, due to Ellis Crasnow, of a conjunctive fork $\langle A,B,C\rangle$ such that C is neither a common cause nor a common effect of A and B. In that example, however, there is a fourth event D which is the common cause of A, B and C. Salmon ([1980], p. 59) had presented Crasnow's case as a counter-example to Reichenbach's thesis about the causal significance of conjunctive forks, but he now acknowledges that, 'as Paul Humphreys kindly pointed out in a private communication, this was an error' ([1984], p. 167 n. 8). I shall here propose another example, which I think is less tame than Crasnow's.

Consider a lottery for which 160 tickets have been issued. Each ticket bears a different three-digit number $d_1d_2d_3$, such that $1 \leqslant d_1 \leqslant 8$, $1 \leqslant d_2 \leqslant 4$, and $1 \leqslant d_3 \leqslant 5$. There is a single prize. The winning number is determined by drawing one ball at random from each of the three urns, U_1, U_2, and U_3, in that order. U_1 contains a sizable amount of balls of equal size bearing,

[1] Salmon adds at once that, as he has 'explained in chapter 6, it appears that conjunctive forks cannot be characterized adequately in terms of statistical relations alone'. One might think therefore that the conjunctive forks which are said to possess considerable explanatory force are not those so neatly characterized by Reichenbach. But I have been unable to find in chapter 6 of Salmon's book—or anywhere else, for that matter—a different definition of conjunctive forks, or an open rejection of Reichenbach's.

in equal numbers, the several digits allowed for d_i ($1 \leqslant i \leqslant 3$). Let n_i denote the digit on the ball drawn from urn U_i. n_i is then the ith digit of the winning number.

Eutychius Loveluck owns 16 tickets numberes 112, 122, 132, 142, 212, 222, 232, 242, 312, 322, 332, 342, 412, 422, 432 and 442. Let A be the event that $n_1 = 1$ and $n_3 \neq 1$. Let B be the event that $n_2 = 3$ and n_3 is even. Let C be the event that Mr Loveluck wins the prize.[1] It does not take long to see that the following relations hold between A, B and C:

$$\begin{aligned} P(A/C) &= 1/4 > 1/12 = P(A/-C) \\ P(B/C) &= 1/4 > 1/12 = P(B/-C) \\ P(A\&B/C) &= 1/16 = P(A/C)P(B/C) \\ P(A\&B)/-C) &= 1/144 = P(A/-C)P(B/-C) \end{aligned} \tag{3}$$

(Note that $A\&B\&C$ obtains only if the winning number is 132 and that $A\&B\&-C$ obtains only if the winning number is 134.)

The triple $\langle A,B,C\rangle$ thus constitutes a conjunctive fork. I do not know whether C can be properly described as a common effect of A and B, but it certainly is not their common cause. Under the circumstances, indeed, if events A and B come to pass, they will have one or more common causes, such as the order given by the lottery supervisor to draw the balls from each urn, or the decision to institute the lottery, or, presumably, the Big Bang. But if the lottery is fair, none of those common causes can be the third term of a conjunctive fork whose first two terms are A and B.

To see this more clearly let us modernise the procedure by which the winning number is determined. Let m_i be the highest digit that a ticket can have on the ith position of its three-digit number. (Hence, $m_1 = 8$, $m_2 = 4$ and $m_3 = 5$.) The winning number will be established by means of a Geiger counter placed successively, for a fixed period of time, in the neighbourhood of three separate chunks of some suitable radioactive material. Let g_i be the number recorded by the counter at the end of its stay near the ith chunk, and let n_i be, as before, the ith digit of the winning number. n_i is given unambiguously by the twofold condition:

$$1 \leqslant n_i \leqslant m_i \quad \text{and} \quad n_i \equiv g_i \pmod{m_i}. \tag{4}$$

Then according to the current understanding of radioactivity, if A and B

[1] As is usual with such examples, I assume that it is certain that the lottery will take place, that the players keep their tickets until the outcome is known, and that the rules of the game and the property laws will not be changed before the lottery is over. Readers who are immoderately fond of precision may incorporate these assumptions into the description of C. Or they can make allowance for the possibility that Mr Loveluck dies or resells some of his tickets, by redescribing C as 'the event that Mr Loveluck or one or more of his heirs or successors wins the lottery'. They must then, indeed, prescribe that none of the said heirs or successors can obtain any tickets except from Mr Loveluck. (As it often happens, to make the story philosopher-proof one may have to end by making it unreadable.)

come to pass, they will not depend on or form a conjunctive fork with any earlier event.[1]

No matter how we arrange the lottery, the statistical interdependence of A and B, entailed by (3), is not due to their issuing from a common cause, but merely to the fact that one of the features of A is a logical consequence of one of the features of B (although A, of course, is not entailed by B). The example could be done away with by restricting conjunctive forks to atomic events. I wonder whether this can give comfort to someone reaching for a realist understanding of probabilistic causality. After all, nobody has yet been able to show that the class of atomic events is not empty in this intricate world of ours.

The example I have presented is notoriously artificial. A slight change in the tickets held by Mr Loveluck will suffice to destroy relations (3) and with them the conjunctive fork $\langle A,B,C\rangle$. For a different choice of tickets held by Mr Loveluck one might still be able to produce a conjunctive fork by giving a different, generally much more far-fetched description of events A and B. Changing the total number of tickets, *e.g.*, to 159 or 161, can have the effect of making insoluble the problem of constructing a conjunctive fork along the above lines. The fact that a conjunctive fork devoid of causal significance can be thus contrived with only the barest minimum of arithmetical ingenuity indicates, to my mind, that the statistical concept of a conjunctive fork that Reichenbach defined by means of relations (1) does not possess the philosophical importance that he assigned to it. Whether an homonymous non-statistical concept will have any significance depends, of course, on how its sponsors propose to define it.[2]

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[1] That A and B do not depend on previous events must be understood to mean that for any such event K to which a probability greater than 0 can be meaningfully assigned, $P(A/K) = P(A)$, $P(B/K) = P(B)$ and $P(A\&B/K) = P(A\&B)$. Since (3) implies that $P(A\&B) > P(A)P(B)$, the triple $\langle A,B,K\rangle$ cannot meet the requirements of a conjunctive fork.

[2] I am very grateful to Paul Humphreys for his illuminating comments on the first draft of this note.